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Gender Equity and Information Technology in Education: The Second Decade

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This article presents a review on gender differences and information and communication technology (ICT) in primary and secondary education. First the rapid development of the use of ICT in education is outlined. Then the topics of access to computers, computer-related learning processes, and educational outcomes are discussed. The review also provides insight into the background of gender differences in participation in computer activities and performance in relation to ICT. The research reviewed focused on the role of teachers and fellow classmates, on the different approaches of girls and boys to ICT, and on the preferences of girls regarding the structure and design of software. The research also analyzed the complex meaning of computer attitudes as both a cause and a consequence of differences in the participation and performance of girls and boys. The extent and nature of these differences vary from application to application.

KEYWORDS: *educational technology, equity, gender differences.*

In 1991 Sutton concluded her review of 10 years of research on race/ethnicity, gender, and social class differences in K–12 educational uses of computers with the observation that there was still a great deal for researchers to do in this field. She identified a need for a deeper understanding of the complexities of inequities in computer use in schools; for research that simultaneously examines race, class, and gender; and for research on which intervention programs work and which elements of these successful programs make them work.

Almost 10 years later, we have made an analytical survey of the literature published during the 1990s on gender differences and computers in primary and secondary education (Van Eck & Volman, 1999).[1] In this article we present the results of this research as a continuation of Sutton's article and give an overview of the developments in the field of gender equity and computers in schools during the last decade.[2] Sutton focused on gender, race, and class but found considerably more research on gender than on the other two characteristics. The accent in our research is on gender differences, and in our literature search we explicitly looked for research dealing with gender in relation to race and class.

Sutton divided her review into three sections: access to computers, processes of computer-related learning, and outcomes. We will do the same in the main part of this article. For each of these three topics we will discuss the changes that have

occurred in research themes since the end of the 1980s, as well as the outcomes of research on new and old themes.

Not only have research themes and outcomes changed; the very term *computers in the school* acquired a different meaning during the course of the 1990s. During the last years covered by Sutton's review, computers began to be used for a wider range of applications in education than just drill-and-practice and programming. Programming is no longer seen as a skill that all students should have, and the use of the computer as a tool has not only increased dramatically but has also taken on many different forms. We will therefore start with a short discussion on the changes that have taken place in the last 10 years in the role that computers play in education. At the end of the article we will revisit the question of how the needs identified by Sutton have been fulfilled and what we see as the questions for the third decade of research on (gender) equity and computers in school.

The Changing Use of Computers in Schools

Since the beginning of the 1990s the use of information and communication technology (ICT) in education has developed rapidly, a development that is reflected in the results of our literature search. During the first half of the 1980s the research was mainly on learning about computers, whereas during the second half of that decade the attention shifted to computer-aided instruction (CAI). The discussion in Sutton's review on this topic only takes up one and a half pages.

An increasingly broader range of computer applications was introduced into education during the course of the 1990s. The term *CAI* has become too general. It is now necessary to differentiate between different sorts of ICT applications when discussing the use of ICT in education. The question of the extent of gender differences in the use of ICT must also be answered differently depending on the application in question. Gender differences can also be manifested in different forms depending on the application used. In 1988 Collis, Kieren, and Kass emphasized that the context and function in which computers are used should be taken into account more when commenting on gender differences in computer use. To be able to place the research results discussed in this article in context, we will give a brief survey in this section of how the use of ICT in education and the possibilities for using it have developed since the end of the 1980s.

During the 1980s many computer applications were developed for educational use; programs for drill and practice, instructional programs, and simulations are now available for many school subjects. Besides these, some more general programs found their way into the classroom, where they are used as learning or work tools (e.g., word processors, databases, and spreadsheets). More recently, Internet and e-mail have become available to schools, offering possibilities for organizing new kinds of learning processes. Recently, strong arguments have been put forward for the introduction of advanced ICT applications as a means of creating a powerful learning environment. This involves new forms of learning and teaching (transformation) in which students deal with knowledge in an active, self-directed and constructive way, leading to learning results that are more transferable to situations outside school than are the results of traditional teaching methods (see, e.g., De Corte, Verschaffel, & Lowyck, 1996; Bransford, Brown, & Cocking, 1999). Bransford et al. (1999) categorize ICT applications according to the way they can help improve education and learning.

First, ICT can contribute to creating learning environments in which students can actively work on solving real problems encountered in daily life. There are

many examples of multimedia programs and simulations that combine text, image, sound, animation, and video to present lifelike problems. There are also numerous projects that feature problems found outside school that experts from outside school help to solve via electronic communication. An advantage of such applications is that authentic and realistic problems can be used in the classroom. Given the previous research on gender and learning, which reveals that girls and women often prefer a way of learning in which they can feel personally connected with the subject matter or at least can see the usefulness of what they are supposed to learn (e.g., Belenky, 1986; Rosser, 1989), characteristics like *authentic* and *realistic* in ICT applications can be assumed to contribute to gender inclusiveness.

A second way that new ICT applications can be used in education, according to the classification of Bransford et al. (1999), is as tools in the learning process or in solving problems. There are simulations that make it possible to visualize complicated abstract concepts and relationships—such as force and movement in physics, complex mathematical functions, or genetic concepts—and to actively manipulate processes in such areas of the curriculum.

A third contribution of ICT to the teaching-learning process is found in the ease with which teachers can give students feedback and with which students can correct their own work. This also stimulates students to reflect. Learning environments that help and stimulate students working together and encourage feedback between them (*groupware,* used for example in computer-supported collaborative learning [CSCL]) have the same effect (Scardamalia & Bereiter, 1994). These ICT applications are often inspired by the principle of collaborative or cooperative learning, which has a whole tradition of research on the role of group composition and on differential effects. Moreover, a preference of girls and women for working together is one of the few gender differences identified with any consistency in the research on gender and learning styles (Severiens & Ten Dam, 1994). Nevertheless, little attention has yet been paid to the differences between students in relation to CSCL.

Last, another contribution of ICT to the "new" learning processes is that it facilitates connections between the school and the outside world. ICT provides access to a vast amount of information. Moreover, the Internet makes interaction and communication possible, not just within the classroom (with classmates and the teacher), but with other classes and schools, even in other countries. Other opportunities for interaction include contact with people and organizations outside the school such as museums, government departments, companies, and universities.

Several advantages of ICT-mediated communication both within the classroom and with persons outside the classroom are mentioned in the literature. (See Fabos & Young, 1999, for a research review.) Students can take their time to react and think more deeply about their response; there is less opportunity for dominant behavior based on social characteristics, and so students who find it difficult to contribute to oral discussions have a better chance. It is also claimed that such applications contribute to the cognitive development of students by stimulating them to articulate ideas, ask questions, participate in discussion and work together, and receive feedback on their ideas from their classmates (Harasim, 1996). This fosters the active construction of knowledge and promotes the development of knowledge from other perspectives. Insofar as international communication occurs, the importance of contact with other parts of the world is mentioned as an advantage (Riel, 1993; Harasim, 1996). Finally, motivational outcomes are also named. Access to a "real audience" is motivating, which in turn contributes to higher achievement

(Cohen & Riel, 1989). The literature on gender differences indicates that an emphasis on the communication aspect of ICT, on interaction and the opportunities for contact with others, will appeal to girls (Gilligan, 1982).

In the following sections we will discuss the extent to which it is possible to substantiate the assumptions formulated in this section—the effects of the educational use of advanced ICT applications on girls—with research findings.

Access

In the following sections we will briefly summarize Sutton's findings during the 1980s and some additional findings of our own arranged by theme (access, process, and outcomes) and then look in more detail at the research carried out in the 1990s.

The first topic that Sutton deals with in her review is access. She describes equality in terms of access to computers at school and at home. When computers were first introduced in the 1980s, gender differences in the use of computers at home and participation in computer activities at school were soon identified. Often the differences were not large, but they were certainly consistent. More boys had a computer at home and used it more often in their leisure time. Girls and women attended computer clubs, camps, and courses in their leisure time less often than boys did and spent less time reading computer magazines. Boys also spent more time at school in front of the computer, during, before, and after lessons. Such patterns were identified in both the United States and elsewhere.

In the 1990s a great deal of attention was still given to gender differences regarding participation in computer education and the use of ICT. The general tendency was that in the home, especially, girls worked less with computers than boys did. Differences between girls and boys in home computer use were identified in studies by, for example, Doornekamp (1993) in secondary education in The Netherlands, Robertson, Calder, Fung, Jones, and O'Shea (1995) in secondary education in England, and Bannert and Arbinger (1996) in German secondary education.[3] Comber, Colley, Hargreaves, and Dorn (1997) and Durndell, Glissov, and Siann (1995) reached the same conclusion in their study on students aged 11 and 12 in the United States and 15 and 16 in Scotland. In the latter study, however, a differentiation was made in the type of use, showing that gender differences do not occur in all types of use. No gender differences were found in use of the computer as a word processor or for playing games. Two years later the Scottish researchers found no gender differences in any type of home computer use by the end of secondary education. However, boys did use computers more often than girls in one another's homes (computer use as a social activity) and more often owned a computer (Durndell & Thomson, 1997).

The second phase of the international Computers in Education (Comped) study (carried out under the auspices of the International Association for the Evaluation of Educational Achievement, IEA) showed that boys still have more access to computers at school in nearly all of the participating countries, with the exception of the United States (Janssen Reinen & Plomp, 1997). Boys also use the computer at school for a wider range of activities than girls. This applies to both primary and secondary education. Several authors in countries as diverse as the United Kingdom, the United States, and Costa Rica (Canada & Brusca, 1991; Schofield, 1995; Huber & Schofield, 1998) point out that it is mostly boys who use the computers at school outside lessons. There are indications, however, that this is changing. Comber et al. (1997) found that in the older age group in their research, the boys used the computer at school more

than the girls but that such a difference did not exist in the younger students (aged 11 and 12). A long-term study in the United States (Rocheleau, 1995) showed that the initial significant difference in computer use by girls and boys in the highest classes of primary education gradually diminished until it was no longer significant in 1992. Neither Doornekamp (1993) nor Durndell and Thomson (1997) found gender differences in the use of computers at school.

However, a gender difference in access to computers at school is still identified in some studies. Other research indicates that this difference may either be diminishing or be related to students' age. However, most of the studies mentioned above give little insight into *how* girls and boys use computers. The studies do not differentiate among various computer applications and various roles in using the computer. Sitting in front of the computer for the same amount of time does not mean that the same work has been done or that just as much has been learned.

Process of Computer-Related Learning

The second theme of Sutton's review concerns educational processes. What happens in schools when students are being educated? A number of issues are discussed under this heading: type of computer use, teachers' attitudes, curriculum, and student interactions. We will see that research on these themes was continued and expanded in the 1990s. In our review we also add a process variable; part of the literature can be categorized as dealing with differences in approach between girls and boys. We will look at this separately.

Type of Use

Sutton concluded that whereas school-related gender differences in overall access were relatively small, differences in type of use were greater. Girls tended to be underrepresented in programming classes, in game playing, and in before- and after-school use. In word processing, however, they were often well represented.

In the 1990s many new ICT applications were introduced into schools. Virtually no research has been done, however, on the use of different applications by girls and boys, although a study has been made of the extent to which gender-specific division of tasks occurs in ICT applications aimed at cooperative learning. We discuss this research under the heading "Student Interactions."

Teachers' Attitudes and Behavior

In the 1980s several researchers pointed out how the role of the teacher contributes to differences between girls' and boys' computer use. The way in which teachers interact with students could easily give students the impression that boys are inherently better at working with computers than girls are (Sanders & Stone, 1986; Schubert, 1986). Little empirical research was conducted on this subject, however. Rosengren et al. (1985) observed that boys were asked more questions than girls in computer lessons in primary schools and that they were given more feedback. Culley (1988) found that teachers in the upper classes of primary schools often considered boys to be more interested in computers, and those teachers enjoyed teaching boys more than girls. Several authors argue strongly in favor of in-service training that will help teachers become more aware of such processes (e.g., Marshall, 1984).

In the 1990s a great deal was expected of teachers regarding the introduction of ICT in schools. Moreover, the introduction of ICT was closely related to a

change in teachers' role from one of transferring knowledge to one of guiding learning processes. Teachers are still depicted in the literature that we examined as the carriers of "hidden messages" about boys' and girls' capacity to work with ICT. They can also play an important role in the realization of more inclusive education. Several studies make recommendations on the role of teachers, based on the research that has been carried out. They must keep an eye on access to computers, provide a counterbalance to the sex-stereotypical behavior of girls and boys (Elkjaer, 1992, Denmark; Volman, 1997, The Netherlands), and be critically aware of the type of software they introduce into the classroom (De Vaney, 1998, United States). Moreover, they must "give a good example" (Janssen Reinen & Plomp, 1993, international; Lee, 1997, United States). These are topics that should figure prominently in the preservice and in-service training of teachers. In Europe there is currently an emphasis on in-service and further training on the technical aspects of the use of ICT (for example, the European computer driving license). Little attention is paid to the pedagogical–didactical aspects of using ICT, with the result that gender differences between students have not been addressed.

The large-scale international IEA–Comped study on the use of computers in primary and secondary education pays attention to the differences between male and female teachers (Janssen Reinen & Plomp, 1993). The authors claim that not only is it important in itself that women teachers be involved in computer education; but the presence of female role models with sufficient skills, knowledge, and positive attitudes is also important in stimulating the participation of girls. Men dominate computer use in the schools in these studies. Women are particularly poorly represented as computer coordinators. In secondary schools, for example, about half of the teachers and only about 20% of computer coordinators are women. Only primary schools in the United States have a high percentage of female computer coordinators, namely 75% (Janssen Reinen & Plomp, 1993).

Nevertheless, most studies found no differences between the computer attitudes of female and male teachers. This applies to the large-scale IEA study (Janssen Reinen & Plomp, 1993, international) as well as to a number of smaller studies that look at the computer attitudes of secondary-school teachers (Dupagne & Krendl, 1992, United States; Robertson et al., 1995, United Kingdom), of students following a teacher-training course (Nash & Moroz, 1997, United States), of participants in a course on "educational computer technology" (Okinaka, 1992, United States), and of teachers in technical education (Gordon, 1993, United States). It should be noted, however, that teachers in the latter two groups might be self-selected for positive attitudes toward computing. However, there is a consistent difference regarding self-confidence and ICT. Janssen Reinen and Plomp (1993) found that male teachers in secondary education had more self-confidence in relation to computers than did female teachers. Women also rate their knowledge and skills lower than men on a self-assessment list. This is an international phenomenon. Robertson et al. (1995) also found that male teachers considered themselves to be more competent than the female teachers considered themselves to be with regard to computer skills. All in all, it can be concluded not only that there are fewer women as role models in schools but also that they present a different sort of role model than men do, as they have less self-confidence in using computers.

Curriculum

Curriculum concerns related to equity focused on two areas in the 1980s: pictures in computer magazines and the representation of women in textbooks and software. Several authors pointed out that very few women were featured in the text and illustrations of magazines, teaching materials, and software and that when they were featured it was usually in a stereotypical way (e.g., Schubert, 1986; Hattie & Fitzgerald, 1987; Culley, 1988).

Research continued in the 1990s on sex stereotyping in teaching materials. Whereas in the 1980s this was often simply a matter of concluding that stereotypes were present in the teaching materials, such statements in the 1990s were supported by empirical research in which teaching materials and software were analyzed carefully. Female characters still are featured less than male characters in software for American primary and secondary schools (Biraihmah, 1993; Hodes, 1996). Non-White and non-Anglo-American characters are also depicted infrequently. Women and people from an ethnic minority background are featured in only a limited number of mostly passive and stereotypical roles, not in positions of power or as active computer users (Brownell, 1992). According to the authors, the restricted and stereotypical way in which ethnicity and gender are presented in many programs conveys a negative message to students and can have an alienating effect on students who cannot identify with the characters in the software (Voithofer, 1996).

A more gender-neutral presentation of characters in software does not, however, seem to be the answer. Students do not find this attractive. Moreover, they seem to attribute a gender themselves, usually male, to genderless figures (Bradshaw, Clegg, & Trayhurn, 1995, United Kingdom, primary education). In the present cultural and social context, which is so dominated by the binary antithesis of man and woman, this strategy is doomed to fail. Several authors argue strongly in favor of developing a range of software that various groups of students can identify with and in which they can find something that inspires and interests them (De Vaney, 1998). Suggestions are also made on how to predict which groups of students particular programs will or will not appeal to. These suggestions include, for example, analyzing the social scripts, particularly gender scripts, in software; developing checklists that software designers and users can use when making or selecting programs; and having prototypes tested by a cross-section of the school population (Volman & Van Eck, 1997).

Empirical research on the effect of software on the attitudes and performance of students scarcely exists. Experiments have been done on the effects of different versions of software that were assumed to appeal more to either boys or girls. Littleton, Light, Joiner, Messer, and Barnes (1992, United Kingdom, primary education) found that gender differences in performance in a computer game disappeared when the masculine stereotyping in that game was reduced. In a follow-up study they investigated the performance of girls and boys in two variations of an adventure game (Joiner, Messer, Littleton, & Light, 1996). Two versions of the game were developed, a "male" version with pirates and a "female" version with princesses. The structure of both versions of the game was identical. Girls scored lower than boys in both versions of the game, even when computer experience was taken into account; but girls scored higher in the version they preferred, usually that with the princesses. Boys had a less pronounced preference for one or the other

version but liked the characters in the pirate version better. No relationship was found between preference and performance with the boys. Given the effect of girls' preference for a particular design of the software on their performance, the researchers emphasize the importance of developing software that is appealing to girls. A possible explanation for the differences in performance, even in the "preferred version," is that not only the characters in the game but also the structure of the game evoked gender-specific reactions.

Student Interactions

Sutton reviews literature that discusses how the "enthusiasm" of boys to get to the computer—including sometimes verbally and physically aggressive behavior (Lipinsky, Nida, Shade, & Watson, 1986)—and their overwhelming presence in computer rooms and clubs (Lockheed, 1986) discourages girls from gaining access. These problems appear to be less likely to occur in well-structured situations (Sanders & Stone, 1986).

Research on patterns of interaction in lessons where the computer plays a central role was continued in the 1990s. The significance of being good with computers for the gender identity of girls and boys proves to play an important role. Elkjaer (1992, Denmark) observed that boys dominate lessons in the optional subject of computer studies for students aged 14 to 15. Boys made spontaneous comments more often, the teacher asked them more questions, and boys were more active in the classroom discussion, even when the teacher explicitly directed his or her attention to the girls. When the computer was used individually, however, there were scarcely any gender differences. The only differences were in the ease with which students indicated that they could not do something (boys found this more difficult) and in helping each other (girls did this more often). Elkjaer therefore stressed that dominance in the classroom should not be confused with competence and that girls should not be seen as the main problem. Boys who are not very good at the subject and try to conceal their incompetence (because being good at the subject of computer studies is part of their gender identity) are the real problem. Similarly, Volman (1997) describes how Dutch boys have the inclination to present themselves as experts in this subject even when they do not know much about computers. Girls are far more inclined to take on the "role of the uninitiated" even when their knowledge and skills are equal to those of the boys. Teachers contribute to this by taking over more quickly at the computer for girls and by assuming a certain expertise in the boys. A qualitative study on primary education in the United States also found that interaction in the classroom was an obstacle for girls (Hanor, 1998). Girls said that the boys in the class belittled them when the girls were using the computer. Factors that the girls mentioned that restricted their access to computers included verbal and physical aggression by boys, not knowing that the computer was free, and lunchtime supervisors' letting the boys have priority.

One of the new applications of computers in education, which was the subject of a great deal of attention in research in the 1990s, is the use of computers in problem solving by students working in pairs or small groups. Working together on the computer is unavoidable in many schools because there are not enough machines for students to work on individually. Moreover, positive cognitive and social effects are expected as a result of working together on the computer. The gender composition of small groups is one of the points of interest in experimental designs

and intervention studies. However, separating the effects of various characteristics of students and of the tasks to be performed is extremely complex; to date, research has not produced unequivocal recommendations for classroom practice. Some researchers found that girls do better in small groups of girls; some researchers argue in favor of such groups on theoretical grounds (Siann & MacLeod, 1986, Scotland; Kirkup, 1992, United Kingdom). Others show that girls perform better in mixed groups (Kutnick, 1997, United Kingdom) or that girls benefit more than boys do from working together (Littleton et al., 1992, United Kingdom). Other student characteristics such as competence and experience in performing the task seem in any case to be equally important, both in primary and secondary education. An explanation for girls' achieving better results in mixed pairs is that they have more opportunity to spend time with the often-more-experienced boys. The question, however, is whether this solution has negative side effects. It may all too easily confirm the image that girls are less competent when it comes to computers. Another solution may be that working in segregated groups compensates for the differences in experience. Tolmie and Howe (1993, Scotland, secondary education) argue strongly for working in small mixed groups because of the differences they identified between the approaches taken by groups of girls and groups of boys in solving a problems (see also "Approach").

Although no unequivocal effects of the gender composition of groups of students were found, research in the 1990s provided clear findings on the process of working together. Boys appear to focus more often on the computer work, whereas girls concentrate more on the group process. Barbieri and Light (1992, United Kingdom) found that in problem-solving tasks on the computer for students aged 11 and 12, girls in mixed groups shared the "turns to use the mouse" more fairly than boys did. In mixed groups, boys made sure that they sat in the right place to use the mouse. Inkpen, Booth, and Klawe (1991, United States) also show that girls working in mixed pairs get less chance to work on the computer.

Ching, Kafai, and Marshall (2000, United States) studied how students worked together on a "learning through design" assignment. A class of 10-to-12-year-olds had to design software for younger students on the subject of astronomy (multimedia encyclopedias). Students clearly attributed different statuses to the various activities involved. Making a report and doing research in the library (i.e., activities with little access to technological tools) had low status. Middle-status activities included word processing and looking up information on a CD-ROM. Programming and searching the Internet were high-status activities. At first, girls were involved mainly with low-status activities, which implicitly involved working less with advanced ICT applications. Once this situation was identified, the teachers successfully intervened with the aim of creating more space for the girls.

In terms of intervention, it seems exceedingly important that collaborative learning be assisted and supported adequately by the teacher. To gain optimal benefit from the opportunities provided by group work, students have to learn to manage the group process, to share the tasks fairly, and to develop an appropriate form of negotiating. The results of structured interventions on this point appear to be promising for both girls and boys (Pryor, 1995, United Kingdom; Ching et al., 2000, United States).

Electronic discussion appeared to have a favorable effect on the participation of girls in classroom discussion. In the research of Hsi and Hoadley (1997), the fact

that the tempo of the discussion could be determined by the individual student and that there were opportunities for reflection and no interventions from more dominant classmates appeared to have a favorable effect on students in lower secondary education in the United States.

Several of the studies discussed show that new ICT applications are accompanied by new patterns of interaction and new roles for students. It is important when implementing new applications to be alert to undesirable patterns and the emergence of one-sided roles. It is also important, during the evaluation, to analyze whether undesirable differences between students have increased or diminished. How to take differences between students into account is a very different question in cooperative learning than in traditional classroom teaching, or in teaching in which students learn individually and with self-direction. When the computer plays a central role it adds an extra dimension. Surprisingly, we have found little research on the division of labor and tasks and its effects in CSCL.

Approach

Various studies carried out in the 1980s showed that girls and boys have a different approach to programming (Turkle, 1984; Hoyles & Sutherland, 1986). But programming is no longer considered to be a basic skill that all students should acquire. As a result, that theme has almost completely disappeared from the research agenda in the 1990s. In the course of the 1980s the idea that gender-specific differences in participation and performance in computer science can partly be attributed to differences in learning style appeared more frequently. Girls and women were thought to learn in a different way than boys and men; computer instruction should take this into account more (Sanders & Stone, 1986). Hence more emphasis should be placed on the possibilities for using computers than on the technical aspects (Marshall, 1984; Hawkins, 1994), and attention should be paid to the history of the computer (Fertsch & Aman, 1985). Software should also be more compatible with girls' interests (Sanders & Stone, 1986). Clarke (1991) argues strongly for cooperative, noncompetitive methods of working.

Not much attention is paid to gender differences in learning styles in more recent research. Research has been done, however, on whether girls and boys have a different approach to some of the new applications and what the consequences are for teaching methods. In the section on student interactions we have already pointed out that girls focus more on the group process when working together on the computer and boys more often concentrate exclusively on the computer itself.

The research of Ching et al. (2000) showed, for example, that girls initially concentrated mainly on organizing and reporting and on solving conflicts. In contrast, the boys focused mainly on getting the work done on the computer and ignored the group process. Girls also appeared to work more slowly because they spent more time exchanging information. It proved possible to give girls more opportunities to participate by regularly reflecting on the group process and positioning the computers differently so that the students could talk more easily about their work.

Hoyles, Healy, and Pozzi (1992, United Kingdom) conducted a study on working in groups on the computer in math lessons in primary education. Here, too, the boys appeared to be more "computer-centric," in the sense that they seized every opportunity to work on the computer. Pryor (1995) came to a similar conclusion in a study of 9-to-10-year-olds working with LOGO and other software in primary

education. Boys appeared to be more task-oriented and girls more process-oriented. Most authors pointed out that the approaches of both the girls and the boys have positive elements. Insofar as interventions in this respect were tried, they aimed to broaden the repertoire of girls and boys.

In 1991 Sutton concluded that most software that had been specifically developed to appeal to girls was not particularly successful. She described the programs as boring and stereotypical. A new trend in the 1990s was research on what, exactly, girls find attractive in software and the development of software that takes this into account. Attention was paid to both the content and the type of program, as well as to design and graphical aspects.

Research indicates that girls still like computer games less than boys do. A conspicuous claim is that many girls find the music used in computer games boring or irritating (Fiore, 1999). A review by Jakobsdottir, Krey, and Sales (1994, United States) concentrated on gender-specific preferences regarding graphics. On the basis of the literature, they made the following recommendations on graphics in software: Findings regarding the content of the pictures indicate that peaceful pictures of people, animals, and plants appeal mostly to girls, whereas graphics depicting people in action or various types of transport and images showing conflict, danger, or excitement appeal mostly to boys. Girls appear to be more interested in colors than boys are and seem to prefer lighter colors. Both girls and boys appreciate details if they are about objects that interest them. Finally, the authors concluded that boys are more attracted to objects that move and that involve action, and to three-dimensional images.

Fiore (1999, United States) formulated a number of recommendations regarding software on the basis of a literature study and interviews with girls aged 5 to 22. She claims that girls prefer adventure, friendship, and creativity in the story line rather than action, violence, and playing to win. They prefer complicated plots and design assignments over simple "rule-based, die-and-start-over" scenarios. The software preferred by girls can involve a broad spectrum of subjects, ranging from looking for solutions for complex social problems to designing interiors and clothes, to bungee jumping and travel. Opportunities for personal exploration are greatly appreciated. Girls want to explore their own feelings and problems, experiment with different clothes and hairstyles, and see how people react to them in certain situations. Girls appreciate it when their own products (e.g., drawings, words, or stories) are included in the story or game. They loathe stereotypes of themselves and games that are too "girly" (e.g., only skirts and no trousers in the wardrobe). They also want sports, helicopter games, races, the choice between a boy and a girl as the main character, and active, tough female characters. In addition, they prefer working together and interactive communication to competition that does not automatically exclude group performance and competition with yourself (self-improvement). Similar conclusions are drawn in the report of the American Association of University Women (AAUW) Educational Foundation (2000).

It is interesting that information on girls' preferences regarding software and websites has been used mainly in the commercial sector and in particular in the United States. Far less use has been made of this information in the development of educational software.

It is difficult to organize the work of Schofield (1995, United States) into Sutton's scheme. Schofield's work transcends the themes differentiated by Sutton and also

has a more sociological perspective than the other research reviewed. Schofield conducted a qualitative study on the introduction of computers in an urban high school and describes how the use of computers both influences and is shaped by the characteristics of the specific school context in which they are introduced. Gender plays a critical role in her analyses. Among other things, she describes how a number of factors reinforce students' existing association of computers with males, e.g., the lack of female computer science teachers, decisions about the names of the computer science courses, and gender-stereotyped course materials. Schofield thus emphasizes that the context in which ICT is used partly determines what the outcomes are.

Outcomes

In the final section of Sutton's review of research, three types of outcome measures are summarized: student attitudes, outcomes of computer-related learning, and traditional school achievement measures using computer-aided instruction.

Student Attitudes

Sutton surveyed a large number of studies on differences in computer attitudes. The assumption on which many of these studies is based is that the underrepresentation and poorer achievements of girls in computer lessons can be linked to their more negative attitude toward computers. Various aspects of students' attitudes toward computers are usually differentiated: computer anxiety, self-confidence, and pleasure and interest in working with computers (Loyd & Gressard, 1984), and the extent to which students find the computer useful (Temple & Lips, 1989; Koohang, 1989; Violato et al., 1989). A final aspect that is differentiated is the extent to which students think in a sex-stereotypical way about computers (e.g., see Vermette, Orr, & Hall, 1986). The results were not unequivocal, but no studies reported more positive attitudes of girls. Sutton pointed out, moreover, that although attitude is regarded mainly as an independent variable, it can also be considered a dependent variable.

Research on the elements of computer attitudes and the connections between them was still carried out extensively in various countries and on different age groups in the 1990s. The same kinds of issues were examined: interests, assessment of one's own abilities, computer anxiety and self-confidence. It is interesting to note that the research is mainly on secondary education. Many researchers find that boys like computers more than girls do and consider them to be more useful (Shashaani, 1994, United States; Makrakis & Sawada, 1996, Sweden and Japan; Comber et al., 1997, United States; Volman, 1997, The Netherlands; Durndell et al., 1995, Scotland; Huber & Schofield, 1998, Costa Rica; Kadijevich, 2000, Yugoslavia). The differences are smaller, however, when experience is taken into account (Comber et al., 1997; Durndell et al., 1995). This does not apply to differences in self-confidence; even when experience is taken into account, girls appear to be less self-confident than boys regarding their computer skills (Robertson et al., 1995; Comber et al., 1997; Volman, 1997; Durndell et al., 1995; Huber & Schofield, 1998).

Some gender differences in the field of educational computer use reflect broader gender differences (e.g., in self-confidence and self-reported competence). However, we think that the fact that these findings are not specific to learning with computers is not a reason to downplay their importance. Rather, such findings may

occur in areas where women do not feel they can be competent as a matter of course. It is significant that working with ICT has become such an area.

In general, older students have a less positive attitude toward computers than younger students do. Gender differences are also greater among older students (Comber et al., 1997; Durndell et al., 1995). However, given the design of the research, it is often not possible to ascertain whether such results are the effects of age or are cohort effects. The fact that younger students have more extensive and varied experience with computers than do older students could have an influence on their attitude.

Students in the 1990s objected to sex stereotyping of computers; girls, in particular, do not think that computers are "something for boys." Girls, however, have fewer plans than boys to continue with ICT at school in the future (Doornekamp, 1993, The Netherlands; Durndell & Thomson, 1997, Scotland; Comber et al., 1997, United States; Volman, 1997, The Netherlands).

D'Amico, Baron, and Sissons (1995, Canada) did a study on the relationship between performance on the computer and personal attributes in the upper classes of primary education. Girls seemed to have more inclination than boys to attribute to luck their achievements in assignments that use the computer as an instructional tool. This finding corroborates findings that girls have less self-confidence than boys in performing assignments on the computer.

Young people's attitudes appear to be linked to those of their parents and to the socioeconomic backgrounds of their families. Kirkman (1993, United Kingdom) and Shashaani (1994, United States) conducted a study on the combined effect of gender and the socioeconomic status (SES) of the family in which a young person grows up on the young person's attitude toward computers. Shashaani (1994) observed that children, particularly girls, from low SES families were less interested in computers than children from high SES families. She assumed that gender roles in lower SES families are more traditional. Kirkman (1993) found that there is a correlation between access to computers and the socioeconomic status of parents—the higher the status, the greater the access and hence the more positive the children's attitude toward computers. This finding applies more to boys than to girls. Kirkman also identified differences in the extent to which parents encourage girls and boys to use the computer.

Attitude has increasingly been featured as a dependent variable in research. Sutton (1991) advocated this approach as early as 1991 and for that reason included research results for the variable "attitude" in the section on outcomes. The question, then, is what factors determine computer attitudes and to what extent they can be influenced. Considering attitude as a dependent rather than an independent variable also changes the place of attitude in the "reasoning" on gender differences. Today girls' attitudes are not only seen as a reason for the limited participation of girls; attention has also been given to determining what causes the differences in attitude: social images, socialization at home and at school, and the pedagogical and didactical characteristics of education itself. Thus attitude has increasingly been seen as a factor that is open to influence. Schofield (1995), for example, points to the fact that there is no inevitable link between gender and reactions to computers. She describes examples of computer activities that girls enjoy and mentions a number of factors that lead to girls' developing less positive attitudes toward computers, e.g., educational practices that emphasize the link in our society between

computing and masculinity, or practices that do not effectively compensate for the initial disparity in prior experience between male and female students. In her study with Huber on a Costa Rican primary school (Huber & Schofield, 1995), it appeared to be student competition in the laboratory, stereotypes about programming, the levels of assistance that students received, and amounts of prior computer experience that were related to gender differences in attitudes toward using LOGO.

A continuing problem in questionnaires on computer attitudes is that usually no differentiation is made between different computer applications. We have already pointed out that a differentiation must be made between applications if one wants to arrive at meaningful conclusions on participation and achievement in computer activities. Differences among applications are also relevant to statements on "the attitude of girls regarding computers." Kay (1992) suggested that the questions who is more positive about computers, who is better at using them, and who uses computers most can best be answered with, "That depends." It depends on what sorts of attitudes are being measured, the skills in question, what the computers are being used for, and the ages of the students. Such differentiations are seldom made in research on computer attitudes. The broader the range of applications for which the terms *computer* and *ICT* are used, the more critical this problem becomes. It also becomes increasingly unclear what researchers are talking about and whether they are talking about the same things.

Computer-Related Competence

Sutton (1991) differentiated two fields in which research has been done on knowledge and skills, namely, computer literacy and programming. Differences to the disadvantage of girls were found in both. This is true of large-scale, international research as well as smaller, more local studies. An exception is the research of Hattie and Fitzgerald (1987). In a meta-analysis of nineteen American studies, they found no gender differences in computer knowledge. Differences in performance appeared, moreover, to be closely related to differences in computer experience. Students who often work with computers perform better than students with less experience, and boys generally have more experience than girls.

Research carried out in the 1990s shows that girls still know less about ICT than boys do. The international IEA studies mentioned earlier in this section (Janssen Reinen & Plomp, 1993, 1997) indicated that boys scored better than girls on a test on the functional knowledge and skills in information technology in the vast majority of countries. Using computers at school resulted in girls' achieving a higher score on this test in all countries. It is therefore particularly important for girls to work with computers at school. Durndell and Thomson (1997) observed that the differences between girls and boys in their knowledge of information technology gradually decreased at the end of secondary education. Doornekamp (1993) found no gender differences in achievements in computer assignments in the first phase of secondary education; in contrast, Volman (1997) found differences comparable to those in the IEA research.

Computer-Aided Instruction

When Sutton published her review, very little was known about the differences between girls and boys in computer-aided instruction. At the beginning of this article we pointed out that the term *computer-aided instruction* is no longer adequate

for the diversity of computer applications now used in schools. In this section we will summarize what is known about the differences in achievements between girls and boys in assignments using computers.

Research in the United Kingdom shows fairly consistently that girls perform less well than boys in problem-solving assignments on the computer, for example, adventures and LOGO assignments (Barbieri & Light, 1992; Blaye, Light, Joiner, & Sheldon, 1991; Underwood, Mcaffrey, & Underwood, 1990; Hughes, Brackenridge, Bibby, & Greenhough, 1988; Sutherland & Hoyles, 1988). These findings appear to be linked with differences in experience with this type of task. There are therefore indications that girls have more difficulty learning with the help of ICT than boys do. Now that ICT plays an increasingly important role in learning in the classroom, it is essential to prevent students who are less technologically inclined than others from lagging behind in computer technology and in other subjects for which the computer is used as a teaching aid. More research is necessary on this topic.

Thus it appears that new ICT applications in education not only offer opportunities for gender-egalitarian education but also pose the risk of new barriers and hidden messages. Working with simulations, CSCL, and other forms of groupware make it possible to create a powerful learning environment. Elements such as "taking differences between students into account," the important role of working together in such a learning environment, and the attention to communication and reflection interface well with the characteristics of gender-inclusive education that are evident in the literature. At the same time, however, new inequalities may emerge. It is therefore essential to remain alert to unequal, gender-specific division of tasks in learning environments in which ICT applications play a role and where students work together on assignments on the computer.

Questions for the Future

Looking back at the need for research on information and communication technology (ICT) in education formulated by Sutton at the beginning of the 1990s, we can conclude that some of her recommendations have been realized and some have not. We can certainly say that a "deeper understanding" of the issue of gender differences in ICT has been realized. Not only have differences been charted in detail, but research has also been carried out on the background of those differences. There is now greater understanding of the role of teachers and classmates, of the different approaches of girls and boys when working with ICT, and of girls' preferences regarding the structure and content of software. The complex meaning of computer attitudes, both as causes and as consequence of differences in the participation and performance of girls and boys, has also been analyzed more clearly.

Sutton's plea for an integral approach to gender, ethnicity, and class was unfortunately not realized in the ensuing ten years. Gender and class were looked at together in just a few studies on computer attitudes. In many studies it is not even clear what the ethnicity and SES of the students are. Intervention programs now exist on a much larger scale than ten years ago and appear to work (Sanders, 1994), but systematic research on exactly what works, in what circumstances, and why is still extremely rare.

Before formulating some suggestions for further research, we will make some general remarks about the research field in relation to our review. First, research

on gender and ICT in education appears to be emerging as a field of interest to researchers working in various traditions and from various perspectives. We encountered research with an empirical sociological angle charting differences in participation; we saw psychological research on attitudes and self-confidence; and educational psychology was present in research on uses of ICT in collaborative learning. This variety implies that the methods used in and theories underlying the research reviewed are diverse. Nevertheless, we found no lively theoretical or methodological debate about gender and ICT in education. One could even say that this field of research is not very strongly developed theoretically or conceptually. One of the challenges for the next decade will be to develop the field further theoretically. Some perspectives were almost absent; for example, we found only a few studies with a more sociological angle.

Second, it could easily be concluded from the studies reviewed that gender patterns regarding ICT are independent of context and locality. However, this should be interpreted in terms of a lack of diversity in the contexts studied, resulting in a false impression of consistency. Schofield's work (1995) directs our attention to the important fact that gender patterns and usage of ICT may vary according to the context. Thus future research into gender differences in educational computer use should explicitly be carried out in various contexts (various schools, various school types and levels, various cultures, various local contexts). Moreover, we emphasize again that ICT is in itself varied; hence, broad questions about its impact are inappropriate and virtually unanswerable.

One of the most striking findings was that little research has been done on the differences between students in specific ICT applications, even though the terms *computer* and *ICT* now refer to a far wider range of applications. The studies we found, moreover, often had few roots in educational practice; they were laboratory-style studies and did not appear to be particularly suitable for solving problems arising from the introduction of ICT in education. If this orientation is to change, we must answer the question, What kinds of differences between students occur when students use particular ICT applications in schools? Research on these applications should focus on differences in *participation, results,* and *approach.* Do various groups of students *participate* in the same way and to the same extent in educational activities in which a certain ICT application is used? Is the learning of different groups of students differentially influenced by the use of this application, and if so, does that influence have differential *results* for those groups? What differences are there in the *approach* of students, in the roles and tasks they take on, the ways in which they fulfill these tasks, and the extent to which differences are a problem? For example, suppose that a student does not learn what is required. In section 2 we mentioned several general assumptions about gender differences in learning (e.g., that girls prefer authentic and realistic learning environments, cooperative learning, and an emphasis on communication). Research could focus on how and to what extent several ICT applications display such "gender inclusive" characteristics and to what extent these characteristics contribute to positive attitudes and achievements for girls. Last, we turn our attention to research instruments that are no longer adequate for studying *attitudes* in relation to the computer. Of particular importance at the moment is the question whether students have different attitudes toward working with ICT as a teaching aid. A differentiation between ICT applications and different contexts must also be made here.

We strongly recommend linking two sorts of research that are often carried out separately at the moment: (a) research on achievements in ICT tasks, which shows that girls score less well, and (b) research on the methods of working and the types of software that girls find attractive. More research is needed regarding which aspects of specific applications (e.g., design, structure, and stereotypes) can account for the effects of using those applications (e.g., achievements, participation, and attitudes). Such research is not only relevant to gender differences. Research on the "digital divide" shows that American Whites and African Americans differ in their ownership of home computers and use of the Internet. Income explains differences in home computer ownership (Hoffman & Novak, 1998). On the one hand, these research results imply that education plays an important role in offering access to computers to students from low-income and African-American families. On the other hand, the results indicate that pupils of different social and ethnic backgrounds differ in their prior experience with ICT. More research on the effects of using ICT on the participation and achievements of students from different ethnic and social backgrounds is therefore required. It is increasingly pointed out that ICT applications in education are probably less accessible and attractive to students from certain ethnic groups as the applications do not interface with the prior knowledge, skills, interests, attitudes and learning approaches of these students (Chisholm, 1995; Freedman & Liu, 1996; Collis & Remmers, 1997; DeVoogd, 1998). We also want to repeat Sutton's plea for an integral approach to gender, ethnicity and class.

Finally, in addition to gender, ethnicity and class, another student characteristic that requires attention is age. Younger students seem to achieve better results in ICT and have a more positive attitude. Gender differences are also less apparent in younger students. Research is necessary to determine whether this is due to the age difference or the general trend that computers play an increasing role in children's lives as a matter of course.

We cannot predict what the role of ICT in education will be in ten years time. It is clear that the use of ICT will become more the norm than it is now. If we guard against the development of undesirable differences between groups of students in different sorts of ICT applications in education, hopefully girls and boys and students from different ethnic and social backgrounds will in principle be equally competent to work with computers as a matter of course.

Notes

[1] The research was commissioned by the Dutch Ministry of Education.

[2] The literature search was done in two Dutch databases (ADION/DION), in ERIC, and in Online Contents, using the descriptors *computer, sex/gender, elementary/primary education,* and *secondary education.* The search produced about 75 relevant titles.

[3] In this article when we talk about differences that are "found" or "identified," we mean differences that are statistically significant, unless otherwise stated.

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